

USE OF GLASS FOR MODELING THE DEPOSITION OF
COAL ASH IN HOT CYCLONES

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ABSTRACT

Tests have been conducted in a laboratory hot cyclone to obtain an estimate of the temperature below which spherical glass particles do not form a firmly attached deposit. A temperature of 800° to 850°C, corresponding to a viscosity between 6.3×10^5 and 2.9×10^6 poises, as calculated from the composition of the glass, was found. We take this viscosity to be approximately that of coal ash above which particles will not deposit in cyclones of fluidized-bed coal gasifiers.

INTRODUCTION

A cyclone operating at temperatures near those of the fluidized bed of the reactor has been used in the gasifier of the U-GAS® pilot plant to remove entrained char particles from the product gas and return them to the bed. Essentially pure coal ash has been found to deposit in this hot cyclone (1). The deposits have been analyzed chemically and examined by optical and scanning electron microscopy. Ferrous sulfide is responsible for deposition under adverse conditions, but deposition of iron-rich ferrous aluminosilicates is the more serious problem. In deposits from Western Kentucky coal, for example, the selective deposition of high-iron siliceous particles is indicated by an $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratio (calculated after excluding the iron contribution of iron sulfide) ranging from 2.2 to 4.6 in the ash of deposits, compared with a ratio of 1.2 in the ash of the coal. The effect of gas temperature (which equals particle temperature) and cyclone-wall temperature on the deposition of such particles was studied in a laboratory hot cyclone in the laboratories of the Mechanical Engineering Department of the University of Wisconsin at Milwaukee (1,2). The particles used in these tests were prepared from pilot plant deposits. The results indicated that the borderline temperature, below which the particles do not form a firm deposit, is about 900°C when gas and wall temperatures are equal.

We envision that the mechanism of deposition involves viscous or plastic flow following collision of particle and deposition surface to create a neck exerting enough surface tension to prevent rebound. We consider that the main cause of flow is impact. Flow driven by surface tension, as postulated by Raask (3) for deposition of coal ash on heat exchange surfaces of boilers, constitutes an additional mechanism leading to firm adhesion. Deposition at the inlet impingement area in the laboratory hot cyclone tests, massiveness of deposits at regions of high gas velocity and acceleration in or near the pilot plant cyclone, and virtual absence of deposits at low-gas-velocity regions of the gasification reactor all indicate that impact of deposition-prone particles plays an important role in the mechanism.

For both mechanisms, however, the effect of temperature on deposition can be attributed to change in viscosity, as surface tension does not vary much with temperature. Investigation of the effect of viscosity with ash particles is difficult, because little is known about the viscosities of iron aluminosilicates and ferrous sulfide at temperatures from 850° to 1050°C and, in any case, the ash particles vary in composition and presence of high melting phases. Therefore, we have chosen to use glass spheres as a homogeneous model material of known viscosity for the study of deposition. We report here a few results of a preliminary nature.

EXPERIMENTAL

The test apparatus consists of a natural gas burner to provide hot flue gas, a dust feeder, and a 9.68-cm ID cyclone (Figure 1). Calculations indicate that the residence time of particles in the hot flue gas is sufficient to heat the particles to the temperature of the flue gas at the cyclone entrance. The inlet section of the cyclone is jacketed to allow cooling of the wall; or alternatively, it can be heated to achieve substantially equal gas and wall temperatures. Temperature readings of the gas during a run are taken by a bare wire thermocouple projecting into the gas just upstream from the inlet section of the cyclone; it is calibrated before the run by an aspiration thermocouple in the inlet section. Temperature of the wall is measured by a thermocouple embedded in it at the spot where the entering gas impinges, where coherent deposits typically form (1,2). The surface of the inlet section is smoothed with No. 320-grit emery paper before each test.

The feed dust in these tests was supplied by the Cataphote Division of Ferro Corporation as Class IV-A uncoated Unispheres of soda-lime glass in a nominal 13-44 μm diameter. A Coulter counter size distribution analysis indicated that the size ranged only between 20 and 51 μm , with 14% greater than 40 μm and 3% smaller than 25 μm .

To determine the borderline of deposition we have made a total of nine runs with the glass spheres, of which seven were within about 50°C of a borderline region obtained by plotting wall temperature against gas temperature (Figure 2). The burner was operated to yield an oxidizing atmosphere at rates giving cyclone inlet velocities ranging from 30 to 50 f/s; these velocities are comparable to those of laboratory tests with particles of pilot plant deposits. Very light but firm deposits of the spheres were observed at the jet impingement area in three of these tests. The results indicate that the borderline for firm deposition with equal gas and wall temperatures is between 800° and 850°C. The slope of the borderline, which should depend mostly on the specific heat of the dust, is assumed to be parallel to the better-established borderline for the pilot plant deposits, which is also shown in Figure 2. In the future, we expect to make additional tests to establish the borderline more precisely and to determine the effect of variables such as velocity and size of particles.

We have chemically analyzed the glass spheres and from this estimated the viscosity at 800° and 850°C by means of the correlation equations of Lyon (4,5). The range of viscosity thus obtained over the above temperature range is 6.3×10^5 to 2.9×10^6 poises. This is near the geometric mean of the viscosities at the softening and working temperatures of glass (5).

DISCUSSION

According to Dietzel's correlation of the surface tension of glasses, glazes, and enamels with composition (6), the surface tension of the pilot plant deposits is up to about 25% higher than that of the glass used here. Neglecting this difference and the effect of particle shape, we may conclude that the effective viscosity of the pilot plant deposit for borderline deposition in the laboratory hot cyclone is in the range reported above for the glass spheres. In the pilot plant or in a commercial plant with much larger cyclones, considerable scale-up is required for application of our results, but we think it likely that they apply there also.

REFERENCES CITED

1. Mason, D. M.; Rehmat, A.; Tsao, K. C. "Chemistry of Ash Deposits in the U-GAS Process." In Fouling of Heat Exchange Surfaces, Bryers, R. W., Ed. Engineering Foundation: New York, 1983.
2. Tsao, K. C.; Tabrizi, H.; Rehmat, A.; Mason, D. M. "Coal-Ash Agglomeration in a High-Temperature Cyclone," Am. Soc. Mech. Eng. [Pap], ASME Annual Meeting, November 1982, ASME Preprint No. 82-WA/HT-29.
3. Raask, E. VGB Kraftwerkstechnik 1973, 53(4), 248.
4. Lyon, K. C. J. Res. Nat. Bur. Stand. Section A, 78A, 1974, 497.

5. Boyd, D. C.; Thompson, D. A. "Glass," in Encyclopedia of Chemical Technology, 11, 807-80. Wiley: New York, 1980.
6. Scholze, H. "Glas-Natur, Struktur and Eigenschaften," 213-21. Vieweg: Braunschweig, 1965.

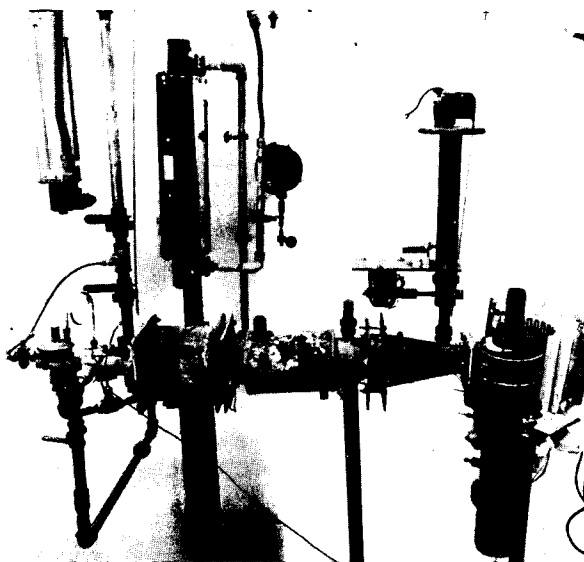


Figure 1. LABORATORY HOT CYCLONE APPARATUS

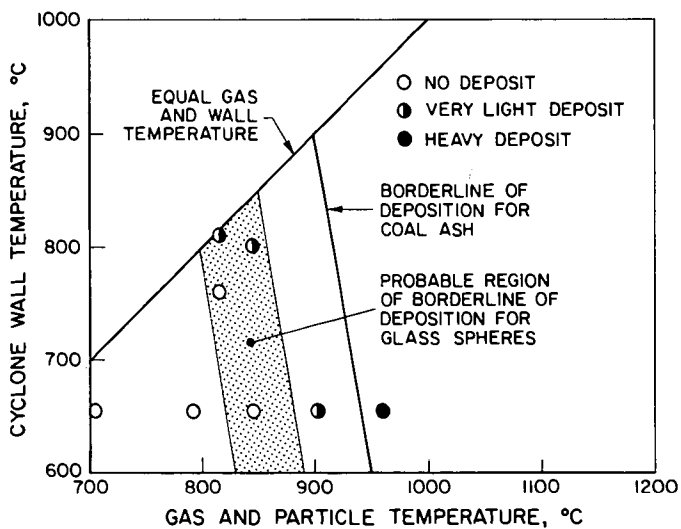


Figure 2. BORDERLINE OF DEPOSITION

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